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INFLUENCE OF WATER DEFICIT AT VEGETATIVE, ANTHESIS AND GRAIN FILLING STAGES ON WATER RELATION AND GRAIN YIELD IN SORGHUM

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SUMMARY

The physiological response of short term water deficits and its relief was assessed on water relations and accumulation of certain metabolites in sorghum hybrid CSH-14 at vegetative, anthesis and grain filling stages. The leaf water potential, osmotic potential and relative water content decreased in the stressed plants at all the stages studied. The decrease in osmotic potential was more compared to decrease in water potential at all the stages indicating the ability of the leaves to maintain turgor through osmotic adjustment (OA). The stressed plants recovered by 48 h after re-watering in terms of all these parameters. Stomatal conductance decreased drastically under stress and recovered partially after re-watering indicating its high sensitivity to water stress. The accumulation of total soluble sugar and free amino acids under stress at all the growth stages indicate the possibility of their involvement in osmotic adjustment. However, the relative contribution of proline and potassium appears to be marginal.

Key words: **Growth stages, metabolites, sorghum, water relations, water stress.**

INTRODUCTION

Sorghum is the major grain crop grown in the tropical and subtropical areas of the world where available moisture is a major limiting factor. Understanding the physiological, biochemical and molecular mechanisms involved in imparting drought tolerance is most crucial for development of stress tolerant genotypes. Several mechanisms, which permit sorghum to achieve economic yields under drought environments have been proposed. These include prolific root system, ability to maintain stomatal opening at lower levels of leaf water potential and high osmotic adjustment. Osmotic adjustment is one of the important mechanisms, which alleviates some of the detrimental effects of water stress (Morgan 1984). It has been identified as an important criterion of yield stability and drought tolerance in several crops including sorghum (Santamaria *et al*. 1990, Ludlow *et al*. 1990, Morgan 1995, Chimenti *et al.* 2002). To understand the physiological response of short term water stress and its relief on water relations, accumulation of metabolites such as soluble sugars, free amino acids and proline were assessed in a sorghum hybrid CSH-14 at vegetative, anthesis and grain filling stages while potassium was measured at anthesis stage.

MATERIALS AND METHODS

Sorghum (hybrid CSH-14) seeds were sown in plastic pots having 14kg of red soil (alfisol) under natural climatic condition during June to October 2000 and three plants were maintained in each pot, which constituted one replicate. Recommended measures were followed to control pests and diseases. Water stress was imposed by

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withholding irrigation at vegetative (35 DAS), anthesis (81 DAS) and grain filling (87 DAS) stages , respectively. The water stress treatment was continued until the plants showed visual symptoms of water deficit stress, which corresponded to 42, 90 and 96 DAS at vegetative, anthesis and grain filling stages, respectively. Water stress was relieved by re-watering the plants at 42, 90 and 96 DAS. Well watered plants were maintained as control. Three replicates were maintained separately without any destructive sampling in both control and water stress treatments until harvest for collecting yield data. Whereas, for destructive sampling there were six replicates in all treatment viz., control and water stress. Out of these six replicates, three were used for sampling just before re-watering and the other three 48 h after re-watering. Weekly average maximum temperature ranged between 27.8 to 33.4^{0}C while minimum temperature ranged from 16.5^{0}C to 22.4^{0}C during the crop growth period.

Plant water stress was quantified by measuring leaf water potential (Ψ_w) (PMS pressure chamber) of the youngest fully expanded leaf (vegetative) or flag leaf (anthesis and grain filling) just before re-watering (at 10.00 h) and 48 h after re-watering. Osmotic potential (Ψ_s) was also measured in these leaves using an Osmometer (Wescor C-5500). Relative water content (RWC) was measured according to Barrs and Weatherly (1962).

Proline, total soluble sugars and free amino acids were estimated in the top most fully expanded leaf at vegetative stage and flag leaf at subsequent stages. K^+ content was estimated in flag leaf at anthesis stages just before re-watering. Proline was estimated according to Bates *et al*. (1973). Total soluble sugars and free amino acids were extracted in 80% ethanol and estimated according to Dubois at al. (1956) and Rosen (1957) for soluble sugars and free amino acids, respectively. K^+ was analyzed by atomic absorption spectrophotometer (906AA GBC, Australia) after digestion with di-acid mixture (Yoshida *et al*. 1976). Data were analyzed statistically using standard procedures.

RESULTS AND DISCUSSION

Leaf water potential, osmotic potential and relative water content decreased in stressed plants at all the growth stages studied. However, the plants recovered by 48 h after re-watering in terms of relative water content, leaf water potential and osmotic potential (Fig.1).

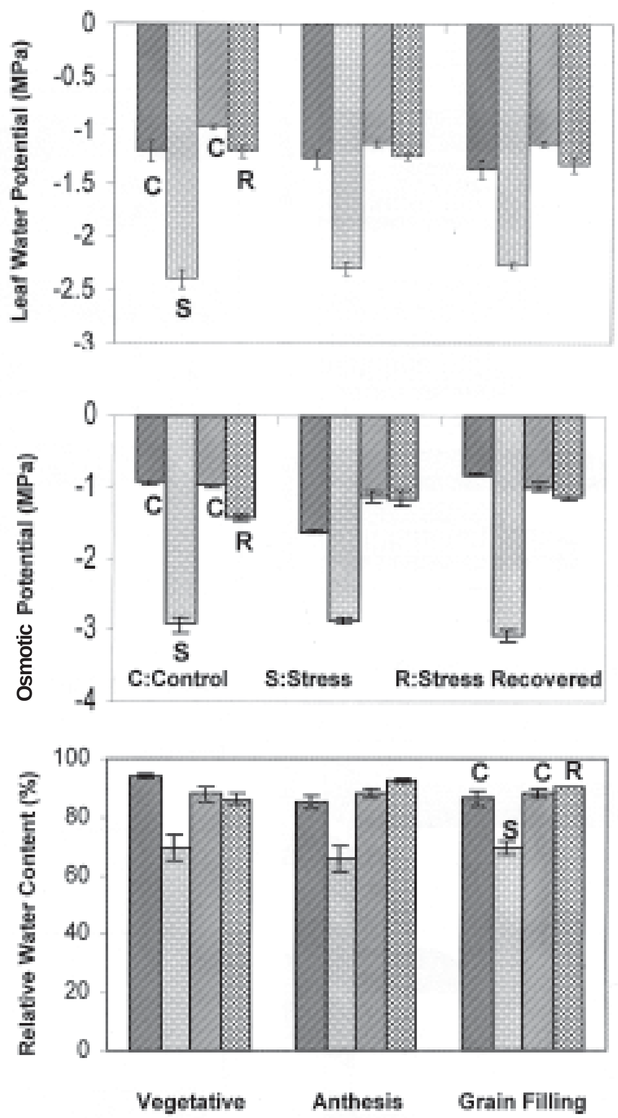

Fig. 1. Leaf water relations in sorghum hybrid CSH-14 as affected by water deficit stress imposed at various growth stages. Control: well watered; Stress: just before re-watering; Stress recovered: 48h after re-watering.

The decrease in osmotic potential in response to water deficit was more compared to the leaf water potential at all the growth stages indicating the ability of the leaves to maintain turgor through osmotic adjustment. Similar to the leaf water potential, the osmotic potential also recovered in 48 h after re-watering (Fig.1). The active reduction in Ψ_s in response to water deficits is known to facilitate maintenance of turgor potential and has been observed in several species (Turner and Begg 1978). Osmotic adjustment of leaves and other organs has been demonstrated in a wide range of species and genotypic variation in OA has been reported in several crops (Morgan *et al.* 1995, Flower and Ludlow 1987).

Total soluble sugar accumulated significantly in the leaves of stressed plants at all the growth stages as compared to well watered controls and declined 48 h after re-watering (Fig. 2). However, it declined to the level of control at vegetative stages, while at anthesis and grain filling stages the sugar levels were higher than control at 48h after re-watering, though their leaf water potentials were more or less similar ($\Delta\ \Psi_w$ 1.05). The free amino acids accumulation was also increased in the water stressed leaves at all the growth stages. These results indicate the possibility of involvement of both sugars and amino acids at the vegetative stage, while at the anthesis and grain filling stage, free amino acid accumulation is more important in OA compared to soluble sugars. Relative accumulation of proline in response to water deficit was in general much higher compared to that of sugars and amino acids. Proline accumulation in response to water deficit was higher at vegetative stages compared to anthesis and grain filling. The recovery of the stressed plants was about 80, 60 and 54 per cent at vegetative, anthesis and grain filing stages to the level of control. Generally, in expanding leaves, initial changes in osmotic potential were largely due to reducing sugars, while amino acids become significant later coinciding with the loss of turgor (Munns *et al*. 1979). In expanded leaves, changes in potassium, sugars

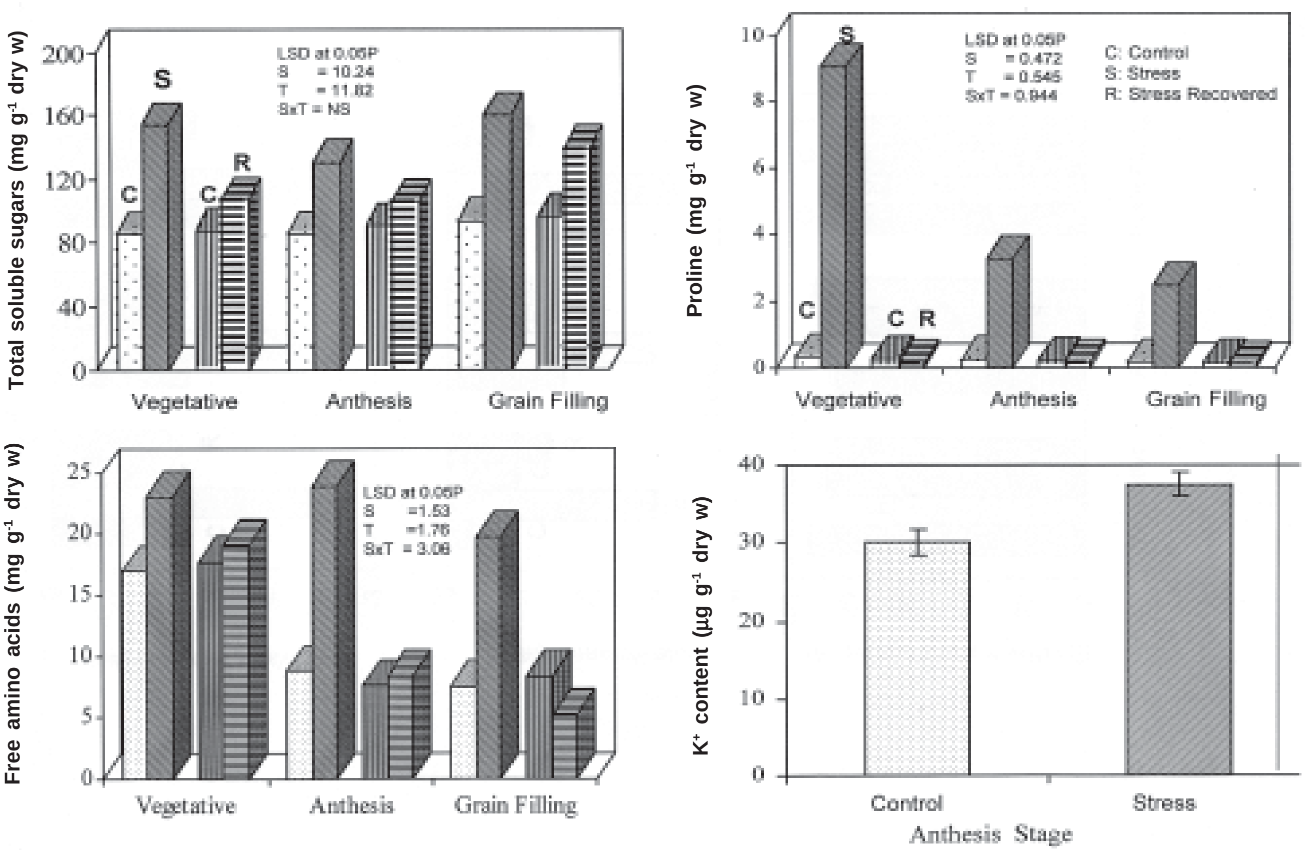

Fig. 2. Total soluble sugar, free amino acid, proline and K^+ levels in leaves of sorghum hybrid CSH-14 as influenced by water deficit stress imposed at various growth stages. Control: well watered; Stress: just before re-watering; Stress recovered: 48h after re-watering.

and amino acids account for most of the changes in osmotic potential. The potassium concentration increased only marginally in response to water deficit at anthesis in this study (Fig. 2). On the other hand, analysis of osmotic components in wheat lines showing high and low OA revealed major differences in accumulation of K^+ followed by amino acids (Khanna-Chopra *et al*. 1995).

Stomatal conductance decreased drastically under stress and recovered partially 48 h after re-watering (Table 1), indicating its high sensitivity to water deficit. Earlier studies have indicated that faster drying plants exhibited lower photosynthetic gas exchange than those experiencing slower drying process (Shangguan *et al*. 1999). Also, stomatal conductance was found to be more sensitive to water deficit than the processes of water loss and CO_2 exchange themselves, which are regulated by it (Lopez *et al*. 1988, Subramanian and Maheswari 1990). Stomata in general are more sensitive to water deficit than photosynthesis (Schulze 1986). Generally stomatal conductance is found to be related with leaf water potential in several forage grasses (Bittman and Simpson 1989).

The dry matter accumulation of plants relieved from stress at vegetative, anthesis and grain filling stages was about 61, 48 and 36%, respectively, lower than the control plants (Table 2). Similarly, seed yield of the (g/pot) stress recovered plants was about 80, 60, 54 per cent lower than the control plants. The seed yield was severely affected when stress was imposed at vegetative and anthesis stages, although the seed growth itself occurred under adequate soil moisture conditions when the stress was imposed at vegetative and anthesis stages. This was largely due to reduction in grain numbers. Reduction in grain number was 72.3, 59.5 and 50.8%, respectively, when the stress was imposed at vegetative, anthesis and grain filling stages. The decrease in grain number observed when plants were stressed at grain filling stage could be due to occurrence of lack of seed filling in this treatment.

From the results of this study it could be concluded that sorghum hybrid CSH-14 maintained lower osmotic potential (Ψs) in response to short term water deficit at vegetative, anthesis and grain filling stages. This could be attributed to higher accumulation of proline, total soluble sugars and free amino acids at vegetative stage, while it was largely due to total soluble sugars and free amino acids at anthesis and grain filling stages.

Table 1. Effect of water deficit stress and subsequent relief on stomatal conductance in sorghum hybrid CSH-14.

Treatment	Stomatal conductance ($cm\ s^{-1}$) Anthesis	Grain filling
Control	1.11±0.04	1.27±0.01
Stressed	0.06±0.01 (95.6)*	0.16±0.01 (87.4)
Control	0.96±0.10	1.18±0.03
Stress recovered	0.78±0.06 (18.7)	0.44±0.01 (62.7)

*Values in parentheses indicate *per cent* reduction over control.

Table 2. Influence of moisture stress on dry matter content, grain yield and its components in sorghum hybrid CSH-14.

Treatment	Total dry matter ($g\ pot^{-1}$)	Grain wt. ($g\ pot^{-1}$)	Grain no. pot^{-1}	1000 grain wt. (g)
Control	59.2	25.6	989	25.9
Vegetative stress	22.9(61.3)*	5.65 (77.9)	274 (72.3)	24.3 (6.2)
Anthesis stress	30.7 (48.1)	10.35 (59.6)	401 (59.5)	25.8 (0.4)
Grain filling stress	37.8 (36.1)	11.8 (53.9l)	487 (50.8)	20.6 (20.5)
LSD at 0.05 P	8.03	4.95	161.9	3.43

*Values in parenthesis indicate *per cent* reduction over control.

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